

# Cob Biomass Production in the Western Corn Belt

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**Abstract** Corn residue is viewed as an abundant, inexpensive source of biomass that can be removed from fields for ethanol production without deleterious production or environmental effects if proper management is used according to some recent publications. Other publications indicate that corn residue needs to be retained on the land to reduce erosion and maintain or perhaps even improve soil organic matter levels. As researchers attempt to address these questions, one component of corn residue that may be available for immediate use for conversion to ethanol is the cob. Our objective was to determine how much cob biomass or cob biomass (as a percentage of grain biomass) is produced that could potentially be converted to biofuels. Results from two long-term experiments: 1) Rainfed with four cropping systems that included corn with three nitrogen fertilizer rates (20 years), and 2) Irrigated with two cropping systems, with four corn hybrids and five nitrogen fertilizer rates (8 years). Several factors (Cropping System, Hybrids, N fertilizer, and their interactions) significantly affected both cob biomass and cob biomass as a percent of grain biomass but were not of sufficient magnitude to be of practical significance. Most importantly, when N fertilizer was applied at rates sufficient to optimize grain yields in all cropping systems and hybrids, cob biomass as a percent of grain biomass averaged approximately 20%. This consistent relationship allows quick and easy calculation of the cob biomass that could be available for harvest for biofuels if grain yield levels or potentials are known.

**Keywords** Biofuel · Cob biomass · Cob percent of grain biomass · Cropping systems · Residue

## Abbreviations

SOC soil organic carbon  
MAP mean annual precipitation  
MAT mean annual temperature

Renewable fuel from conversion of plant biomass to ethanol has the potential to replace a portion of the liquid transportation fuels now derived from fossil feedstocks [6, 1]. Development of herbaceous and woody plants as biomass energy crops was a research focus of the U.S. Department of Energy (DOE) from 1978 to 2002 [8, 9], but funding for this research was largely discontinued in 2002 and the focus shifted to use of crop residues for biomass energy.

The predominant crop residue proposed as a biomass feedstock is from corn (*Zea mays* L.). Corn stover, the aboveground plant material including the cob remaining in the field after grain harvest, is viewed as an abundant, inexpensive source of biomass that can be removed from fields without deleterious production or environment effects if proper management is used [6, 1]. Since crop residues are also a source for soil organic carbon (SOC), which is essential for maintaining soil productivity [4, 7], the verdict is still out as to whether there is sufficient corn residue available for both functions. Johnson et al. [5] suggests 12.5 Mg ha<sup>-1</sup> stover would be required to maintain SOC in a corn-soybean [*Glycine max* (L.) Merr.] under moldboard plow tillage and 5.25 Mg ha<sup>-1</sup> for continuous corn and conservation tillage. Wilhelm et al. [17] report these amounts far exceed the mass of corn stover needed to control wind and water erosion on ten highly productive soils throughout the prevalent corn growing region in the United States.

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One component of corn residue, the cob is mentioned as a potential feedstock for ethanol production (e.g. <http://www.projectliberty.com/> and <http://www.cvec.com/>). The advantage of using the cob as the source of biomass feedstock is that it is already entering the combine, it is a smaller more dense material, and it requires only small modifications for it to be harvested. For example, Shinnars et al. [13] state their single-pass combine collects 30% of the stover (a large percentage of it being the cob) when equipment with an ear-snapper head is used. Since the cob is a more dense and less bulky material to harvest than corn stalks and leaves, it would require less additional equipment for harvest, transport, and storage. Also, it would leave the more bulky material of stalks and leaves [11] on the soil for soil protection and improvement.

Although historically corn has been harvested on the ear and then shelled for a shelling percentage, very few reports on cob mass relative to crop grain yield or total biomass exist. Hanway [2] reported cobs represented 17% of the corn stover or 9% of the total aboveground dry matter (including grain). Given the lack of information on cob biomass and the apparent advantages of its use, we sought to determine how much cob biomass is produced for potential conversion to biofuel in current hybrids and cropping systems at several N fertilizer levels in both a rainfed and irrigated environment.

## Materials and Methods

### Rainfed Experiment

The first experiment was located on the Agronomy Farm at the University of Nebraska Agricultural Research and Development Center near Mead, Nebraska on an Aksarben silty clay loam (fine, smectitic, mesic Typic Argiudoll). This site has an average organic matter content of 31 g kg<sup>-1</sup> and soil test P and K levels in the very high categories in the surface 75 mm (according to University of Nebraska Soil Testing Laboratory fact sheets). The experiment is rainfed with a Mean Annual Precipitation (MAP) of 760 mm and a Mean Annual Temperature (MAT) of 10.5°C.

Seven cropping systems (three monoculture, and two 2-yr and two 4-yr systems) with three rates of N fertilizer were included in the study. Only results from the cropping systems including corn were evaluated: continuous corn, corn-soybean, and oat [*Avena sativa* (L.)] +clover [80% *Melilotus officinalis* (L.) and 20% *Trifolium pratense*]/grain sorghum [*Sorghum bicolor* (L.) Moench]/soybean/corn and soybean/grain sorghum/oat+clover/corn. Each phase of the 2-yr corn-soybean and 4-yr oat+clover/grain sorghum/soybean/corn and soybean/grain sorghum/oat+clover /corn systems

occurs every year. Treatments were assigned to experimental units (9 by 32 m) in factorial combinations of cropping system and crop within cropping system in five randomized complete blocks in 1982. No fertilizer N was applied to any of the cropping system plots that growing season.

Three subplots (9 by 10 m) separated by 1 m alleys were randomly assigned a 0, low, or high N rate within each whole plot treatment starting with the 1983 cropping season. Nitrogen rates were 0 kg, 90 kg, or 180 kg N ha<sup>-1</sup> for corn and sorghum and 0 kg, 34 kg, or 68 kg N ha<sup>-1</sup> for soybean. Nitrogen was sidedressed as liquid urea-ammonium nitrate solution (28-0-0) in 1983 and 1984, and broadcast as granular ammonium nitrate (34-0-0) in subsequent years. Nitrogen applications were made in late-May or early- to mid-June for all three crops.

Cultural practices were similar to those used by local farmers. Previous crop residue on corn and sorghum plots was shredded in mid- to late-November each year. All plots were tilled once or twice with a tandem disk just prior to planting each year. Crop varieties and hybrids were evaluated and changed if necessary every 4 years at completion of each full cycle of the 4-yr cropping systems. Corn was seeded in 76-cm rows at approximately 47,000 seed ha<sup>-1</sup> in early-May as soil conditions permitted. Weed control was accomplished using combinations of broad-spectrum herbicides in pre- and post-emergent applications, cultivation, and hand weeding. Herbicides were selected for each cropping system to obtain optimum weed control and to reduce carryover problems for successive crops in that cropping system. Soybean and grain sorghum were seeded in 76-cm rows at rates of approximately 370,000 and 173,000 seeds ha<sup>-1</sup>, respectively. Both crops were planted in mid- to late-May or early-June according to conditions each year. Weed control and herbicide selection for each crop were accomplished using the same criteria described above for corn. Aboveground dry matter samples (1 row by 5m) for corn were collected each year soon after physiological maturity. Ears were removed; stalks were cut at ground level, chopped, dried, and weighed for stover dry matter yield determination. The ears were dried at 65°C, weighed, and shelled. Shelled grain was weighed to determine grain yields and cob yields were determined by subtracting the grain weight from the ear weight. Yield data were adjusted to 155 g<sup>-1</sup> kg<sup>-1</sup> for corn. Additional background and management information can be found in Peterson and Varvel [10].

### Irrigated Experiment

The second experiment was an irrigated monoculture corn and soybean-corn cropping systems study located in the Platte Valley near Shelton, Nebraska on a Hord silt loam (fine-silty, mixed, superactive, mesic, Cumulic Haplustoll).

**Table 1** Mean squares and their significance for year, cropping system, N rate, and interaction effects on corn cob dry matter and percentage of grain production at Mead, NE from 1987 to 2006

Source of variation	df	Cobs	
		Yield	% of grain yield
		Mean squares	
Year (YR)	19	10.17 <sup>b</sup>	2722.4 <sup>b</sup>
Block	4	0.17 <sup>a</sup>	34.6
Error a	76	0.17	49.8
Cropping System (CS)	3	3.39 <sup>b</sup>	362.1 <sup>b</sup>
YR × CS	57	0.25 <sup>b</sup>	79.9 <sup>b</sup>
Error b	240	0.11	31.6
N Rate (N)	2	17.45 <sup>b</sup>	43.9
YR × N	38	0.26 <sup>b</sup>	57.2 <sup>b</sup>
CS × N	6	1.19 <sup>b</sup>	93.9 <sup>b</sup>
YR × CS × N	114	0.10	40.4 <sup>b</sup>
Error c	640	0.06	20.8

<sup>a</sup> Significant at the 0.01 probability level.<sup>b</sup> Significant at the 0.001 probability level.

MAP and MAT for the site are 635 mm and 9.7°C, respectively. A split-split-split plot design with cropping systems as main plots, corn hybrids as subplots, and N fertilizer regimes as sub-subplots with four replications was used. All phases of the monoculture corn and soybean-corn systems were present each year. Four commercially available Pioneer<sup>1</sup> brand corn hybrids differing in yield potential and maturity were used in both cropping systems including corn. Hybrids 3162, 3379, 3394, and 3417 were used from 1993 to 2000. All corn hybrids were planted between late April and mid May in 8-row (91-cm row spacing) by 15.2-m long plots at approximately 74,000 seeds ha<sup>-1</sup>. Soybean in the soybean-corn cropping system was planted in early to mid May using production practices typical to the area. Irrigation was provided as needed with a linear drive sprinkler system.

Nitrogen fertilizer, as ammonium nitrate, was broadcast on the soil surface for both crops in late May or early June. Fertilizer N regimes included N fertilizer rates of 0 kg, 50 kg, 100 kg, 150 kg, and 200 kg N ha<sup>-1</sup> for the 1993–2000 growing seasons.

Aboveground dry matter samples from an area 0.91 m wide by 3.04 m long for corn were collected each year soon after physiological maturity. As in the first study, ears were removed; stalks were cut at ground level, chopped, dried, and weighed for stover dry matter yield determination. The

ears were dried at 65°C, weighed, and shelled. Shelled grain was weighed to determine grain yields and cob yields were determined by subtracting the grain weight from the ear weight. Yield data were adjusted to 155 g kg<sup>-1</sup> moisture. Additional background and management information can be found in Varvel and Wilhelm [15].

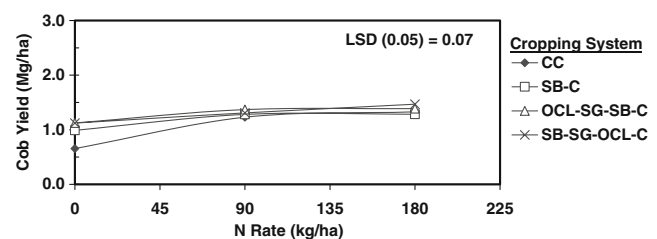
### Statistical Analyses

We analyzed the effects of the different variables at the Mead and Shelton locations to determine their effects on cob biomass and also cob biomass as a percentage of the amount of grain produced. These two variables were selected because it was important to determine both how much cob biomass was being produced and whether it was a fairly consistent or highly variable amount in relationship to the grain biomass produced. In addition, most estimates of stover yield are made by assuming a harvest index or grain to stover ratio and applying that to crop yield data reported in the NASS databases (National Agricultural Statistics Service) <http://www.nass.usda.gov/QuickStats/index2.jsp>. Similar computation will be required for cob yield because these data are not available directly in any broad scale databases.

Data from both studies were analyzed over years both within and across cropping systems and N fertilizer rates to determine whether responses were significant using PROC GLM. Both years and cropping systems were considered as fixed effects in the models for both experiments and main effects and interaction effects were tested with the appropriate pooled error terms within each experiment. All statistical analyses were performed using PC Version 9.1 of the Statistical Analyses System for Windows [12].

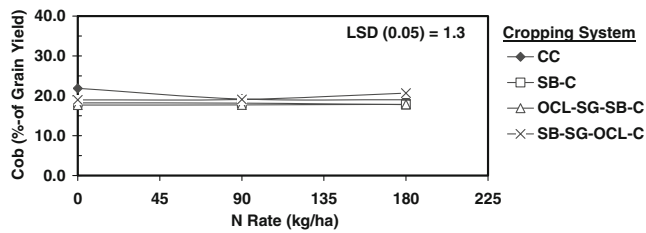
### Results and Discussion

Cropping System and N fertilizer rate main effects and Year × Cropping System, Cropping System × N Rate and Year × N rate interactions all significantly affected cob



**Fig. 1** Cob dry matter yield in four cropping systems at three N fertilizer rates in a long-term study at Mead, NE from 1987–2006. The LSD value can be used to compare N rates within cropping systems and vice versa

<sup>1</sup> Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by the authors, USDA-Agricultural Research Service, or the Agricultural Research Division of the University of Nebraska.



**Fig. 2** Cob dry matter yield as a percentage of grain yield in four cropping systems at three N fertilizer rates in a long-term study at Mead, NE from 1987–2006. The *LSD* value can be used to compare *N* rates within cropping systems and vice versa

biomass (Table 1) in the rainfed experiment at Mead. These effects are very similar to those reported by Peterson and Varvel [10] for grain and total dry matter yields from this same experiment in the early years of the study. Although several significant interactions were observed (Table 1), absolute differences were not of much practical significance as is demonstrated by the data shown in Fig. 1 for the effect of the Cropping System  $\times$  N Rate interaction. The significant interaction was obtained because the magnitude of the response to N rate was slightly different

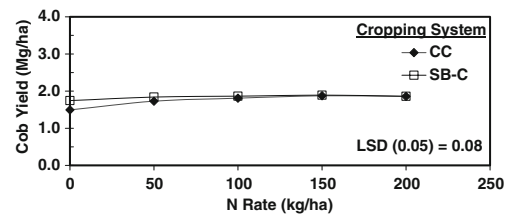
**Table 2** Mean squares and their significance for year, cropping system, hybrid, N rate, and interaction effects on corn cob dry matter and percentage of grain production at Shelton, NE from 1993 to 2000

Source of variation	df	Cobs	
		Yield	% of grain yield
		Mean squares	
Year (YR)	7	29.15 <sup>c</sup>	8731.9 <sup>c</sup>
Block	3	0.36	81.4 <sup>a</sup>
YR $\times$ Block	21	0.36 <sup>a</sup>	58.7 <sup>a</sup>
Cropping System (CS)	1	2.47 <sup>c</sup>	1027.9 <sup>c</sup>
YR $\times$ CS	7	0.19	235.6 <sup>c</sup>
Error a	24	0.16	28.3
Hybrid (H)	3	0.79 <sup>c</sup>	41.8
YR $\times$ H	21	0.31 <sup>b</sup>	48.7 <sup>c</sup>
R $\times$ H	3	0.10	33.1
YR $\times$ CS $\times$ H	21	0.11	13.8
Error b	144	0.14	17.7
N Rate (N)	4	2.86 <sup>c</sup>	743.9 <sup>c</sup>
YR $\times$ N	28	0.18 <sup>c</sup>	146.2 <sup>c</sup>
CS $\times$ N	4	0.64 <sup>c</sup>	179.6 <sup>c</sup>
H $\times$ N	12	0.06	14.6
YR $\times$ CS $\times$ N	28	0.09	80.1 <sup>c</sup>
Y $\times$ H $\times$ N	84	0.08	12.4
CS $\times$ H $\times$ N	12	0.06	6.3
YR $\times$ CS $\times$ H $\times$ N	84	0.07	13.0
Error c	768	0.09	13.3

<sup>a</sup> Significant at the 0.05 probability level.

<sup>b</sup> Significant at the 0.01 probability level.

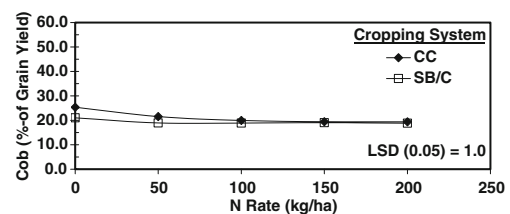
<sup>c</sup> Significant at the 0.001 probability level.



**Fig. 3** Cob dry matter yield from 1993–2000 in two irrigated cropping systems at five N fertilizer rates in a long-term study at Shelton, NE. The *LSD* value can be used to compare *N* rates within cropping systems and vice versa

between cropping systems and essentially was obtained because of the very low cob yields in the continuous corn system at the 0 level of applied N fertilizer (Fig. 1). Cob yields in all of the other systems were greater at the 0 level of applied N fertilizer because of N that became available from the previous legume in those cropping systems which has increased grain yields in those same cropping systems [15].

Similar results were obtained for cob percent of grain biomass (Table 1) in the rainfed experiment. Again, the Cropping System main effect and the Year  $\times$  Cropping System, Cropping System  $\times$  N Rate, and Year  $\times$  N rate interactions were all significant. In addition the Year  $\times$  Cropping System  $\times$  N Rate three way interaction was significant, but the main effect of N Rate was not (Table 1). Again, although several significant interactions were observed (Table 1), absolute differences were not of much practical significance as is demonstrated by the data shown in Fig. 2 for the effect of the Cropping System  $\times$  N Rate interaction. Similar to the results obtained for cob yield above, the significant interaction was obtained because in the continuous corn cropping system with 0 N applied, cob percentages were the greatest because the cobs were small and contained few kernels (Fig. 2). These results demonstrate that in spite of several significant interactions, cob percentages averaged approximately 20% in all cropping systems, regardless of N rate (Fig. 2). It is also none too surprising that several significant interactions were obtained given the large amount of data collected over the 20 years of the study, but when examined closely most of those



**Fig. 4** Cob dry matter yield as a percentage of grain yield in two irrigated cropping systems at five N fertilizer rates in a long-term study at Shelton, NE from 1993–2000. The *LSD* value can be used to compare *N* rates within cropping systems and vice versa

differences were extremely small and of very little practical significance as can be seen in Fig. 2. Again as was reported above, most of these significant interactions were due to the fact that in the continuous corn cropping system, grain and cob yields at the 0 level of N are greatly reduced.

In the irrigated experiment at Shelton, similar responses to those reported above for the rainfed experiment were obtained except in the irrigated experiment there was the additional variable of corn hybrid that was tested. Cropping System, Hybrid, and N fertilizer rate main effects and Year  $\times$  Hybrid, Year  $\times$  N rate, and Cropping System  $\times$  N Rate interactions all significantly affected cob biomass (Table 2). These results were similar to those reported by Varvel et al. [14] for grain yield from this same experiment in the early- to mid- 1990's. Differences between Hybrids, although significant, were essentially related to the difference in yield potential between the hybrids tested [14]. The response shown in Fig. 3 for the Cropping System  $\times$  N fertilizer rate interaction best demonstrates the type of response obtained. Small differences over several years can result in highly significant effects even though agronomically they are of little consequence and in this case, they are mostly due to lower yields in the continuous corn system when no fertilizer N was applied.

Similar results were obtained for cob percent of grain biomass (Table 2) in the irrigated experiment. Again, Cropping System and N fertilizer rate main effects and Year  $\times$  Hybrid, Year  $\times$  N Rate, and Cropping System  $\times$  N Rate interactions were all significant. In addition, Year  $\times$  Cropping System two-way and Year  $\times$  Cropping System  $\times$  N Rate three-way interactions were significant, but the main effect of Hybrid was not (Table 2). These results are best demonstrated by the data shown in Fig. 4 for the two-way Cropping System  $\times$  N Rate interaction. In spite of some year to year variation, it is obvious that the differences between the two cropping systems occur at N fertilizer rates that are insufficient for optimum yields (Fig. 4). Several interactions were also significant, but as can be seen by the absolute differences in Fig. 4, their overall effect is minimal.

In spite of significant treatment (Cropping System, Hybrid, N fertilizer rate) interaction effects on both cob biomass and cob percent of grain biomass in both experiments, the amount of cob biomass as a percent of the grain biomass was very consistent (Figs. 2 and 4). As would be expected, the amount of cob biomass is correlated to the amount of grain biomass, which is why the hybrid effect becomes nonsignificant with respect to cob biomass as a percentage of grain biomass in the irrigated experiment (Table 2). Additionally, this percentage was fairly consistent at 20%, especially when N fertilizer has been applied at a rate sufficient to optimize yields (Figs. 2 and 4). This number is similar to that reported by Hanway [2], but less

than that of Shinnars et al. [13]. Using this relationship, a quick calculation can be made of the potential amount of cob biomass that would be available for harvest if the producer has some idea of his potential grain yield. Although it is not a direct calculation of the biomass of cob that is available, its consistent relationship to grain yield across cropping systems and hybrids when sufficient N for optimum yields makes it an easy way to obtain the amount of cob biomass that would be available.

Research demonstrates that this stream of biomass is generally greater in irrigated than in dryland studies, but only because the yields are usually greater. Corn cobs are a potential source of biomass because they are already in the harvest stream and all it would require is a few modifications to harvest this resource. Prototype systems for grain and cob harvest and other fractional schemes already exist [3, 13]. The main advantage of this source of biomass is that with some slight modifications to the combine, since it is already being handled, it would just be a matter of finding a practical way to accumulate it and then haul it away from the combine. It is also a much less bulky material, which would reduce hauling and storage requirements greatly.

It also appears that in environments similar to the locations of these two experiments, removing the cobs would be a possibility only in the irrigated continuous corn situation. In that environment, the amount of corn residue (stems, leaves) produced would still be at or above the 6 Mg ha<sup>-1</sup> level, even if the cobs were removed [16]. That amount of corn residue has been cited by Johnson et al. [5] in an intensive review of the literature as the amount required to maintain soil organic C levels, in many cases, a proxy for soil quality.

Our results do demonstrate that current cropping systems or hybrid actually have little to no effect on cob production levels when fertilized with the optimum amount of N fertilizer other than by their direct effect on yield. However, very little is known about the actual effect of removing cobs on either soil erosion or soil C. Further testing is needed to assess and quantify those effects in these and other environments as well.

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